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Seabird Island Monitoring

INTRODUCTION

The Seabird Island demonstration project (figure 1) was designed and constructed to promote and demonstrate sustainable approaches for the design and construction of First Nation housing. The project, located near Agassiz, B.C., consists of seven housing units configured in four buildings – one duplex (units 1 and 2), one triplex (units 3, 4 and 5), and three single-detached units (units 6, 7 and a conventionally constructed house).

Units 1 to 7 employ many features to reduce energy consumption and environmental impact while promoting sustainable resource use and healthy indoor environments. Solar orientation was the driving force behind the design of the site, the form of the houses and their placement. Climatic factors also influenced the form and details of the buildings. Steel roofs with large overhangs were provided to protect moisture-resistant, cedar-clad exterior walls from the high volumes of rain experienced in the coastal climate of British Columbia. As well, a rain-screen cladding system was used.

Each unit has a high-efficiency, condensing, natural gas water heater supplying space heating through a combination of forced-air and radiant-floor heating. The heater also supplies domestic hot water. The attached solariums were designed to provide solar preheating of the domestic hot water and supplemental space heating via in-slab ducts in the living room floor.

Ventilation air preheating was provided with a system of earth tubes that would use the relatively constant ground temperature to temper incoming ventilation air. A forced-air system to collect air heated under the steel roofs was also included to help offset space heating needs. The project also featured three wind turbines to assess the potential contribution of wind-generated electricity to offset conventional electricity sources.

The solar roof, solarium and domestic hot water preheat were integrated into a single system. Air was drawn with a fan under the dark metal roof whenever the air under the roof was warmer than the control thermostat setting. Air was also drawn from the peak of the solarium through a vent entering the same duct and adjacent to a back-draft damper isolating the under-roof duct. This air then passed around an uninsulated water preheat tank located under a window seat in the solarium. From there, the air either passed out through an exhaust vent (summer) or through ducts in the floor slab into the living room (winter) to supplement space heating.

An earth tube ventilation system was installed to provide tempered ventilation air for each of the seven units and consists of 92 m (302 ft.) of underground 10 cm (4 in.) diameter, unperforated, "Big O" tubing. Whenever the upstairs thermostat calls for heat, the circulation fan forces air through a hot water coil and at the same time a ventilation fan draws air through the underground ventilation tubes.

Three wind turbines were installed. One was a vertical-axis turbine (that was never made operational) and the other two were horizontal-axis wind turbines.

Figure 1 Seabird Island demonstration project

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RESEARCH PROGRAM

Objectives

To assess the extent to which the many innovative features influenced the performance of the dwelling units, Canada Mortgage and Housing Corporation initiated a research project to monitor and assess several of the systems. The research evaluated the following aspects of the project:

- energy performance;
- wind energy systems;
- solar energy systems;
- earth tube ventilation systems;
- installation/operation;
- user friendliness; and,
- durability.

The monitoring program documented energy use in all seven units and provided more detailed information on the performance of the innovative systems installed in unit 7. Indoor air quality was also measured with several spot tests with a focus on the performance of the earth tube system.

Methodology of the Monitoring Program

Natural gas and electrical meter readings were collected monthly for all seven units and the conventionally constructed dwelling unit to provide a comparison. Monitoring was carried out from February 2005 to March 2006.

A weather station was installed to monitor outside temperature, outside relative humidity, horizontal insolation, wind direction and speed, and rainfall during the monitoring period. Inside temperature and relative humidity, ground-tube ventilation temperature and relative humidity output to house were also logged with additional sensors.

A monitoring system was installed in the conventional house to monitor and log inside temperature and relative humidity. A data logger and associated sensors were installed in unit 7 to monitor sunspace and mechanical system temperatures and flows. Additionally, the occupants were surveyed with respect to their impressions of the performance of their homes.

RESULTS

Energy Performance

The monitoring provided important insights and feedback regarding the many innovative features that the community wanted to explore in the design and construction of the dwelling units. An energy performance rating of EnerGuide 80 was achieved, which is comparable to R-2000 homes.

However, overall, the monitored energy consumption of the dwelling units incorporating the innovative features ranges from 97 per cent to 142 per cent of the conventionally constructed unit but comparisons are difficult due to the different housing types.

The monitoring revealed that unit 7 used a total of 26,870 MJ/year of energy for utilities (appliances, including gas cooking, lights, fans and pumps), about 11,490 MJ/year of natural gas for domestic hot water and 42,851 MJ/year of natural gas for space heating, for a total of 81,211 MJ/year. These amounts correspond to 33 per cent for utilities, 14 per cent for DHW and 53 per cent for space heating. Monthly energy consumption by end use is shown in figure 2.

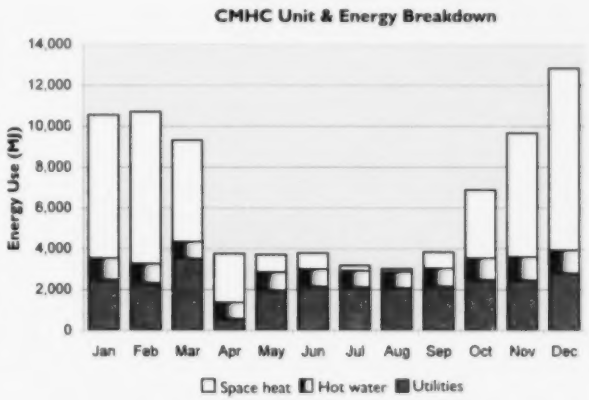

Figure 2 Unit 7 monthly energy consumption by end use

While unit 7 and the conventional unit appeared to use about the same amount of energy on an annual basis, the latter was kept at almost 5°C (9°F) colder during the winter. In comparison, unit 7 was maintained at about 23°C (73°F), while the conventional unit was operated at about 18°C (64°F) — with the result that unit 7 used slightly more energy than the conventional unit for space heating. This result highlights the difficulty in comparing the energy consumption performance of houses with different operating conditions.

Calibrated HOT2000 simulations were performed to allow unit 7 and the conventional unit to be compared given similar operating conditions. Using the models from the calibrations, simulations were performed with the same conditions of occupancy, and long-term average weather.

Results of these simulations (figure 3) showed that unit 7 would use 37 per cent less space heating energy and 28 per cent less water heating energy when compared to the conventional unit under similar operating conditions. The savings would amount to a total of 26,697 MJ/year for a typical family of four living in unit 7 when compared to the conventional house. A well-insulated and airtight building envelope and high-efficiency space and water-heating systems in unit 7 contributed to the energy savings.

Default Operating Conditions, Long-Term Weather

	Space heat MJ/year	DHW MJ/year
Conventional	50,516	27,330
CMHC unit 7	31,597	19,552
Savings	37%	28%

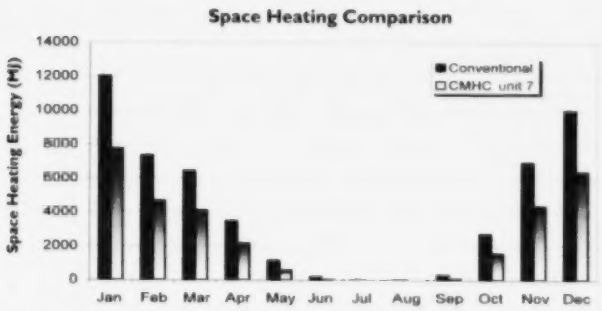

Figure 3 Reconciled monthly spacing heating comparsion: unit 7 and conventional dwelling units

Wind Energy

The monitoring revealed that wind, as a renewable energy source, at the Seabird Island location was not sufficient to justify the installation of the wind turbine. The horizontal-axis wind turbines (HAWT) produce power only if the wind speed is greater than about 3 m/s. However, winds greater than 3 m/s occurred at Seabird Island less than 22 per cent of the time and winds greater than 7 m/s (which would allow the turbine to generate about 50 per cent of its rated electricity output), only about three per cent of the time. As a result, only 1,271 kwh per year were produced by the two HAWT units. This points to the need to conduct careful site surveys of wind conditions in advance of deploying wind energy systems. The vertical-axis wind turbine was never made operational.

Solar Energy System

The solar steel roof/solarium energy system did not perform as well as expected. In particular, problems were experienced with the air handling system (control system set points, system configuration, manual controls, fan energy consumption) designed to collect heat from the solar roof and attached atrium.

As well, the occupants did not always set the system appropriately given the season, which could result in overheating in the atrium and the dwellings. It was also estimated that the energy required to operate the fan recovering heat from the roof and atrium would be more than the energy recovered. Under some operating conditions, the fan could also pressurize the home and contribute to conditions that could cause moisture problems in the building envelope.

If, as happened in some cases, the solarium exhaust vent was left open in the winter, cold air from outside cooled the water preheat tank and froze the water lines.

The solarium itself provided limited passive solar gain as the occupants kept the blinds shut and the door separating the solarium to the house were shut throughout the monitoring period. The atrium provided no usable heat and the back-draft damper was found to be an annoyance to the occupants, since it opened and banged shut during windy periods.

Earth Tube

With respect to the earth-tube ventilation system, the monitoring found that it provided limited heat and its overall contribution to providing ventilation was uncertain. It was noted that the system was set up to operate only during cold periods, which offered only limited incremental benefit as during such times infiltration through the building envelope is increased (due to higher indoor-outdoor temperature differences) and the additional ventilation air from the earth tubes was least needed.

Several leakage points were found around the area where the tubes come out of the slab ("Big O" tubes to metal ducts) and at the entrance to the plenum (metal ducts to plenum), which resulted in minimal flow through the earth tubes themselves. The mold testing indicated that there could have been exposed soil in the earth tube tested.

Installation/Operation/User-Friendliness

While systems were generally installed in accordance with the design drawings, a number of deficiencies were noted. Leaky ductwork, non-operational dampers and poorly integrated control systems were among the key observations.

Many of the systems were found to be unnecessarily complex in design, difficult for the occupants to understand and control and hard to maintain. Some of the systems worked independently of one another and sometimes at cross purposes. The occupants did not always understand how to optimize solar heat recovery from the steel roof and atrium.

Durability

Other than minor issues associated with installation, durability issues were very minor in nature.

CONCLUSIONS

Overall, the monitoring found that the energy-efficient integrated space and water heater and the relatively efficient building envelope contributed most to the energy efficiency of the houses. All things being equal, the Seabird Island homes are relatively energy efficient in comparison with conventional homes.

However, several of many innovative features in the houses such as the earth-tube system and solar energy roof /atrium systems did not perform as expected and tended to be overly complex. Nevertheless, it should be noted that the occupants were generally happy with the performance of their homes. In a number of respects, the project demonstrates both the successes and challenges of designing and constructing sustainable housing that relies on relatively complex approaches to achieving high performance.

IMPLICATIONS FOR THE HOUSING INDUSTRY

The Seabird Island project provided an opportunity to implement and assess a wide range of innovative green design and construction features. While the Seabird Island First Nation community is pleased with the homes constructed and their performance, the monitoring project demonstrated the need to keep systems and equipment simple, easy to understand and easy to operate, maintain and control.

Furthermore, the monitoring demonstrated the need to ensure that innovations are appropriate for the climate, location and overall applications and can be easily designed, installed and commissioned to help ensure optimal performance.

In this regard, a priority should be placed on the passive elements of housing design such as passive solar design and heavily insulated, airtight building envelopes as opposed to relatively complex active mechanical systems. This approach can be advantageous in terms of the overall performance of housing and the return on investment.

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Housing Research at CMHC

Under Part IX of the ***National Housing Act***, the Government of Canada provides funds to CMHC to conduct research into the social, economic and technical aspects of housing and related fields, and to undertake the publishing and distribution of the results of this research.

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